

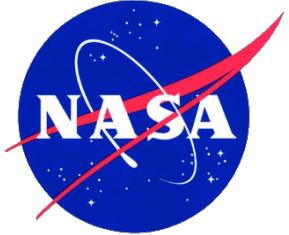


# NASA Water Recycling Technology Development

## A summary of the proposed State of California/NASA Water Recycling Demonstration Project

**Michael Flynn**  
NASA Ames Research Center



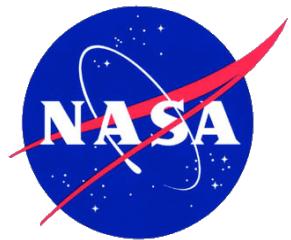


# Relevance to California

1. The availability of water is impacting economic development and residents lives.
2. The environmental impact: About  $\frac{1}{2}$  of all rain water that falls on California is diverted to human use. This percentage will increase in the future. Blaine Hanson, Department of Land, Air and Water Resources, University of California, Davis
3. Water costs are one of the most inflationary commodities. This is a result of infrastructure replacement and maintenance costs.

## Unfunded infrastructure cost estimates

	Water (next 20 year)	Sewer (next 10 years)
USA	\$ 348 Billion	
CA	44 Billion	\$45 Billion
Reference	EPA 2011 Drinking Water Infrastructure Needs Survey: Fifth Report to Congress.)	The American Society of Civil Engineers (ASCE) 2013 <i>California Infrastructure Report Card</i>



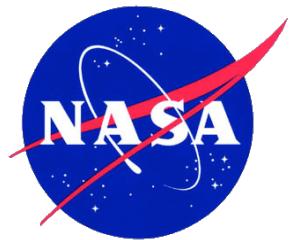
# Rate of Inflation of water over the Last 12 Year

San Francisco  
+211%

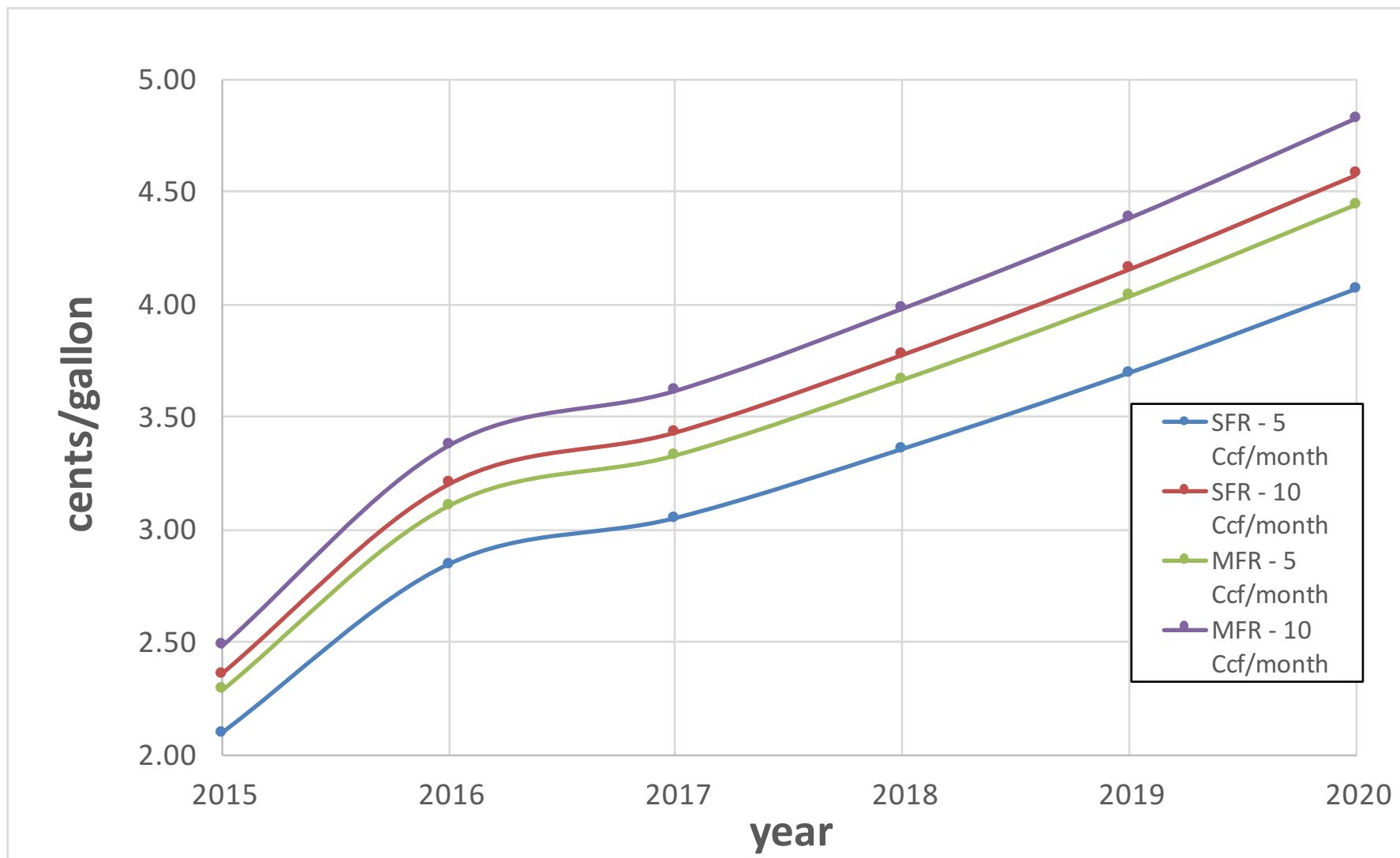
San Diego  
+141%



Inflation per 12 years	Inflation Per year
38%-70%	3%-6%
71%-89%	6%-7%
90%-129%	8%-11%
130% - 233%	11%-20%

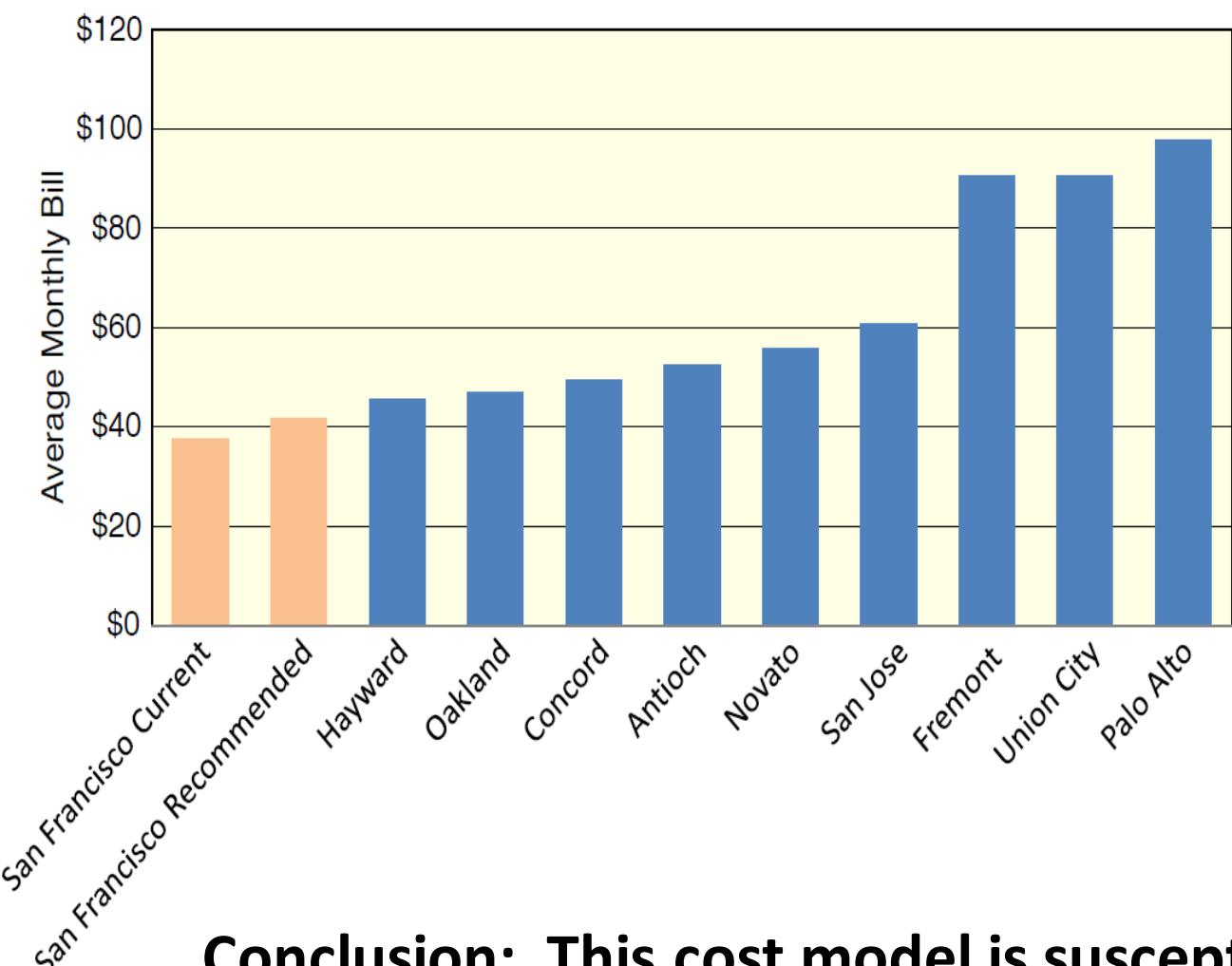


# Cost Analysis using San Francisco Water and Sewage Data



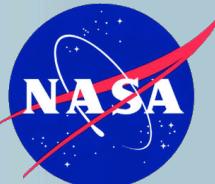


# Comparison of SF Water Cost to Region and World Wide (2014)

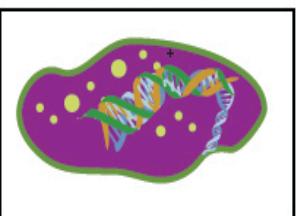
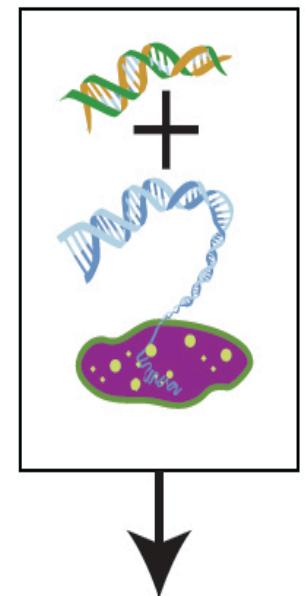
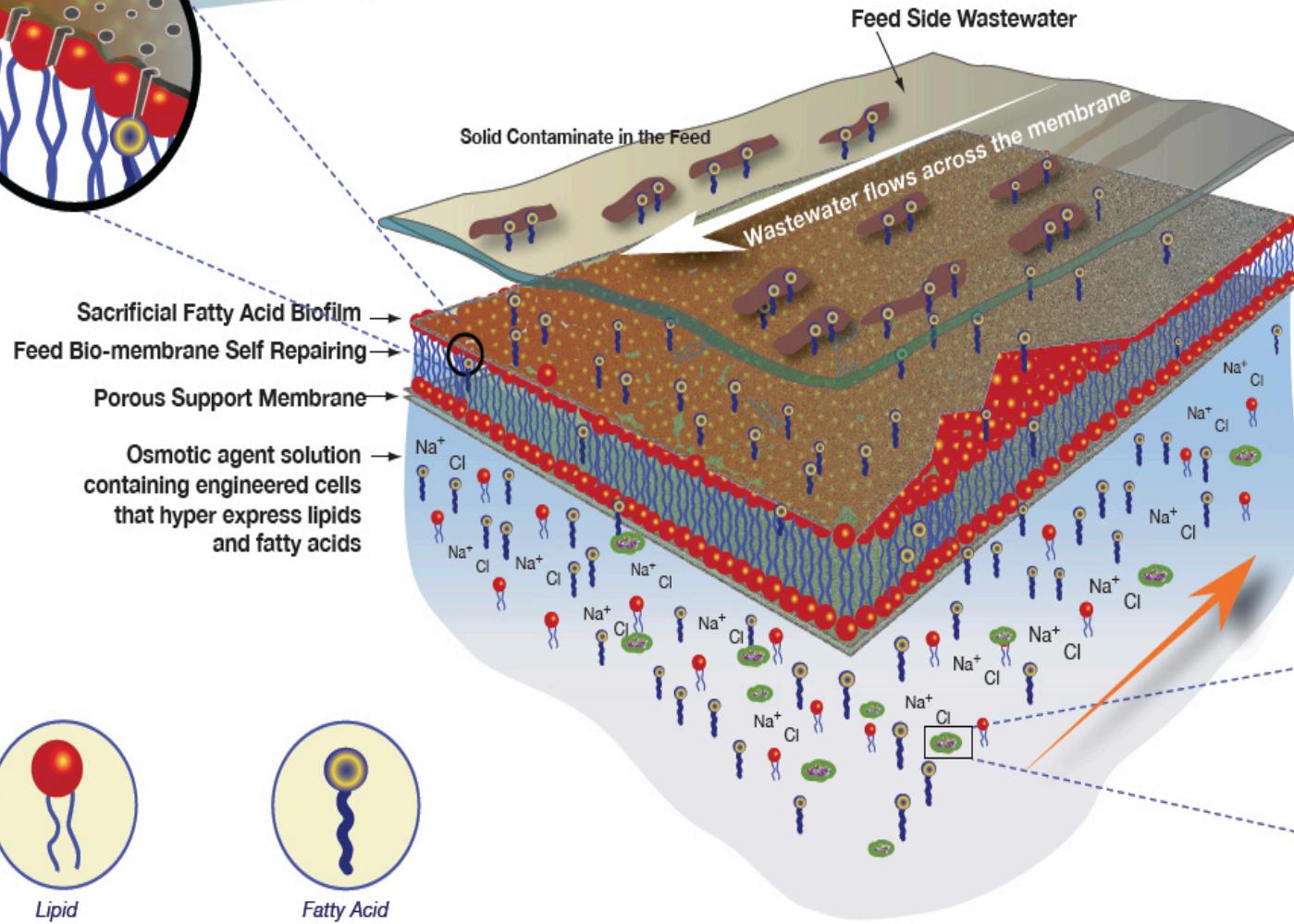
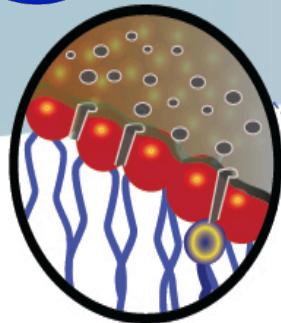


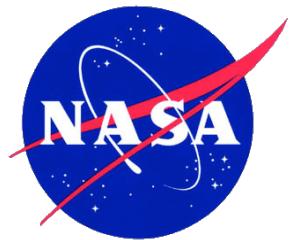
Country	\$/cubic meter
Germany	\$1.91
Denmark	\$1.64
Belgium	\$1.54
Netherlands	\$1.25
France	\$1.23
UK - Great Britain & N. Ireland	\$1.18
Italy	\$0.76
Finland	\$0.69
Ireland	\$0.63
Sweden	\$0.58
Spain	\$0.57
United States	\$0.51
Australia	\$0.50
South Africa	\$0.47
Canada	\$0.40

**Conclusion: This cost model is susceptible to disruption from innovation and consumer empowerment.**

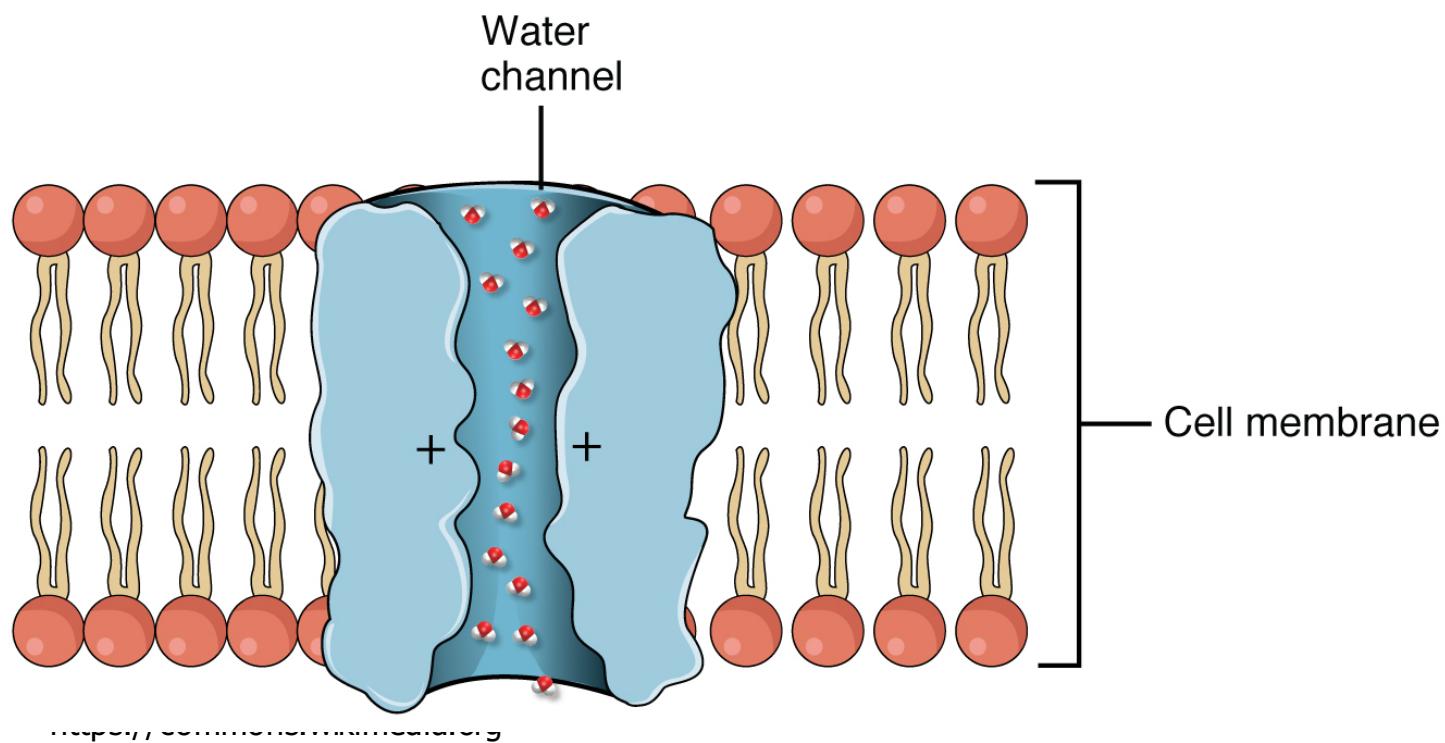


# Bio-membrane



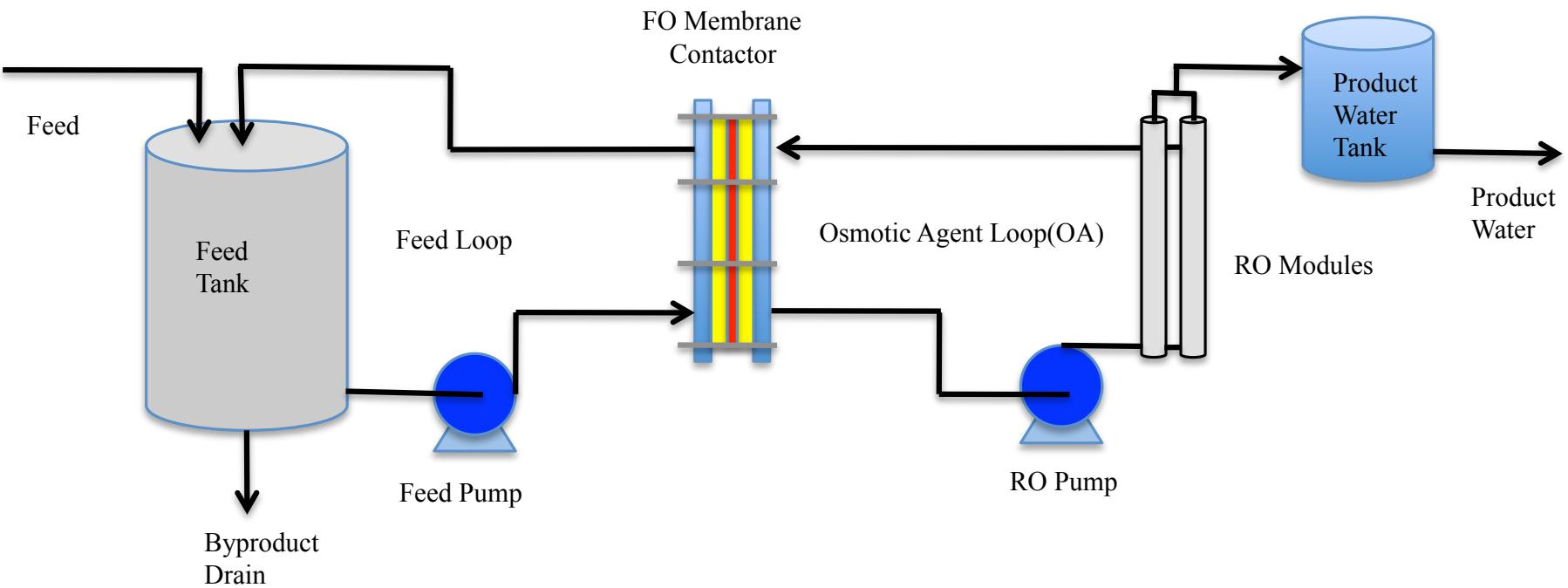


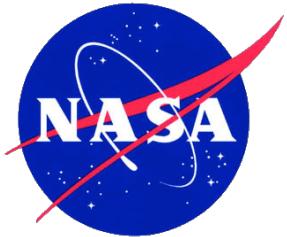
# Aquaporin Membrane





# Sustainability Base Gray Water Recycling System





# Transferring NASA Technology and to Address Water Scarcity in California

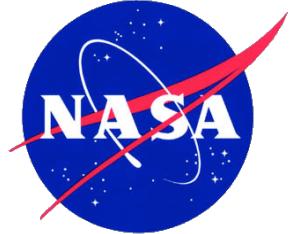
**It is one thing to say it is safe but its another to prove it is safe.**

- Requires long term operational testing.
- Requires statistically valid operational test that address both public health and human factors issues.

## NASA approach

- Use fail safe systems and limit online testing.
- Small scale distributed systems (in home or in business) at an economical scale.
- Produce potable water, even for non potable use.
- Continually study human factors and health effects.
- Develop systems designed to autonomously operate for extended periods.
- Apply automation and predictive failure approaches to reduce operational costs.

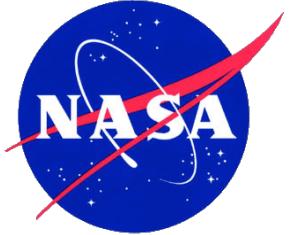
**Empower the consumer to solve the consumers problems.**



# State of California/NASA Water Recycling Demonstration Project

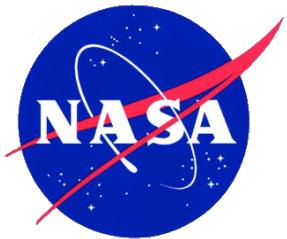
The objectives of the pilot project are to:

- Demonstrate the applicability of on-site greywater reuse for washing machines and toilet flush applications.
- Evaluate recycled water quality performance and public health impact.
- Evaluate consumer perceptions about recycled water and associated technologies.
- Evaluate the economics of on-site consumer-scale water recycling.
- Develop recommendations to inform regulations, policy, and product development pathways that will enable wide-scale adoption and of onsite water recycling.

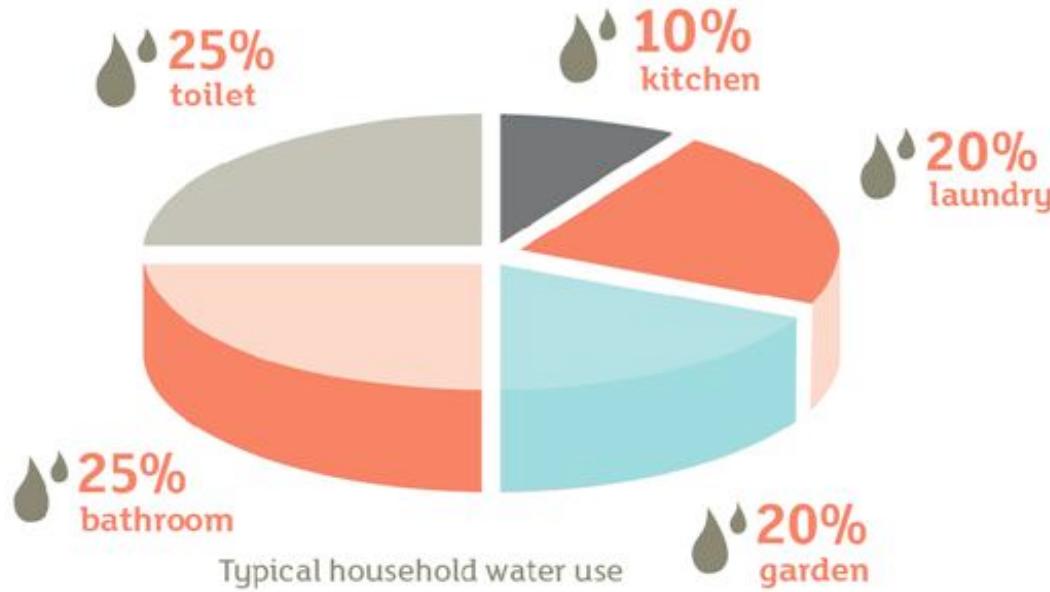


# State of California/NASA Water Recycling Demonstration Project

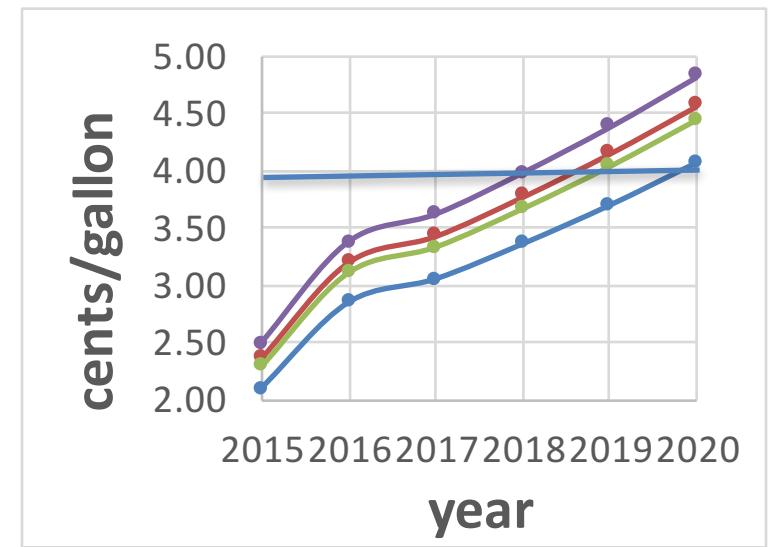
- A collaboration between
  - National Aeronautic and Space Administration (NASA)
  - Research Triangle Institute (RTI)
  - Sustainable Silicon Valley
  - City of San Jose
  - Santa Clara County
  - Mercy Housing
  - Ecumenical Hunger Program
  - Others (TBD)



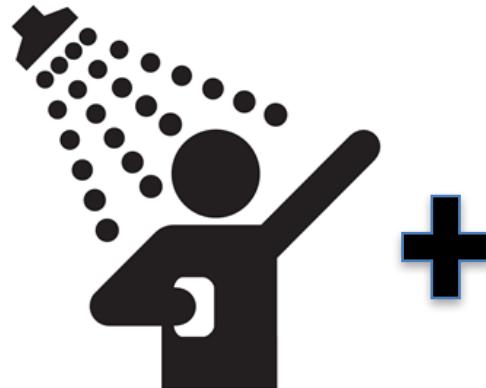
# Why Graywater?

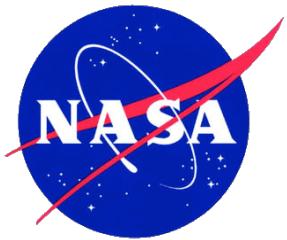


San Francisco Data



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# Target Consumer Solutions



## Water Recycling Clothes Washer

- 90% water recovery
- **Saves on average 675 gal/person year**
- Low installation costs
- May not require a permit
- Does not require double plumbing



## Gray Water to Toilet

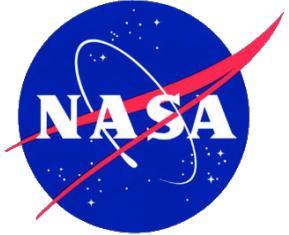
- 75-85% water recovery
- **Saves on average 750-850 gal/person year**
- Higher installation costs
- Will require a permit
- Double pluming required is limited to inside bathroom only

5 L/hr NASA Forward Osmosis System



12 L/hr NASA Forward Osmosis System



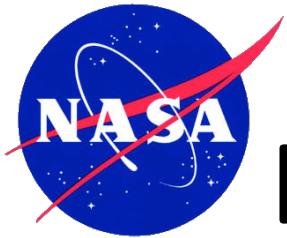


# Human Studies

Approach: To ensure that the research ethics, public health and the human factor aspects are addressed.

This project will include oversight from the following review and technical advisory boards:

- An independent institutional review board (IRB) – to ensure research ethics and safety protocols are in place and to provide final selection approval for test sites.
- An external human factors advisory board – to advise the team on best practices in studying the impacts of social, economic and political factors impacting technology adoption.
- An external public health studies review board – to advise the team on best practices and correlative research surrounding public health impacts of water reuse.

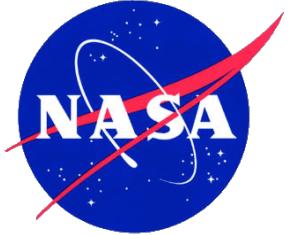


# Demonstration Site Selection

Although the demonstration sites will ultimately be determined by the IRB Board, an initial identification of sites has included:

- A residential lodging facility at Moffett Field
- An office building at Moffett Field
- Several apartment complexes in San Francisco
- A community center in East Palo Alto
- A public/commercial space in San Jose
- A corrective facility in Santa Clara.
- Other TBD sites

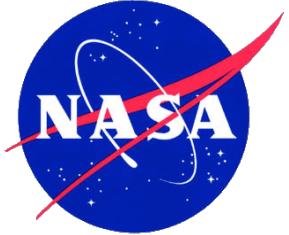
The sites have been selected to draw users from different demographic settings and backgrounds and will therefore deliver insights to inform adoption strategies across a range of populations.



# Data Collection Protocols

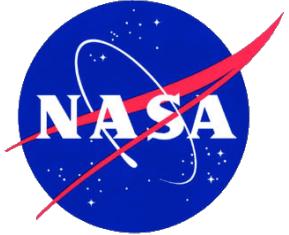
These sites will involve demonstration, observation, and experimentation activities over a 36 month period aimed at delivering technology exposure, quality assurance, and user feedback on applications.

- Demonstrating technical performance. System performance will be monitored routinely, along with routine safety and operational checks.
- Soliciting and analyzing user preferences. Demonstration at site will involve experimental and observational studies using interviews, surveys, and user focus groups to gather user preferences related to system design, function, and cost. The user evaluation will involve data collection to gather insights across a range of demographic groups, and will document gender, age, income, and social and cultural variables in findings related to technology adoption. Survey protocols will be defined and disseminated across sites to ensure consistency in methods used across the sites. Instruments used in data collection will be implemented and designed consistently across sites, to bring broadly generalizable findings to the study.
- Testing educational and product messaging. Beyond just demonstrating the water products themselves, the test sites provide a venue for exploring public education about water reuse. Leveraging installations at each locality will allow for preparation and testing of education and product messages about water reuse as applied across the various appliances.



# Impact

- Empower consumers to solve States water scarcity problems.
- Future cost savings to users.
- Provide tool for consumers to meet mandated water use reductions.
- Municipality savings from differed infrastructure costs.
  - Facility capacity enhancement displacement
  - Defer enhancement of distribution system
  - Transfer costs from municipality to the consumer
- Environmental benefits from reductions in State water diversions.
- Enable development in water limited applications.
- Generate commercial opportunities in the State through private sector investment.



# Problems

- Federal laboratories are no allowed to receive State funding, with some exceptions. State policy
- Not a good fit between State funding mechanisms and project objectives.
- Lack of Proposition 1 funding.
- Concern do to potential disruption of status quo.

# Issues

1. General issue of State funding to Federal Laboratories.
2. Establishment of State funding mechanisms to address safety and regulatory issues associated with on site reuse.
3. Feedback to insure needs of the State are meet.